Comment on "Absence of Compressible Edge Channel Rings in Quantum Antidots"

(Dated: February 2, 2008)

In a recent article, Karakurt *et al.* [1] reported the absence of compressible regions [2] around antidots in the quantum Hall regime. We wish to point out a significant flaw in their analysis, which invalidates their claim.

The presence of compressible regions around antidots was proposed by us [3] in order to explain the so-called "double-frequency Aharonov-Bohm oscillations" [4, 5]. The model considers Coulomb blockade [6] of tunnelling into compressible states formed around an antidot. Karakurt *et al.* measured the temperature dependence of the double-frequency Aharonov-Bohm resonances, and fitted the data to two theories, one considering resonance through a single state (Eq. 4 in Ref. 1) and one with multiple states (Eq. 2) [7]. The measured temperature dependence matches that already observed in Ref. [6] and follows the behaviour predicted by the first theory, and they claim that this shows that there are no compressible regions, in which multiple states are pinned near the Fermi energy E_{F}.

However, Karakurt *et al.* overlook the fact that the multiple-state theory is only valid for a ladder of single-particle states with a fairly constant density of states. It predicts a temperature-independent tunnelling conductance because thermal broadening increases the number of states involved in tunnelling in proportion to the temperature T whereas the tunnelling through each state decreases as $1/T$.

It is not clear whether compressible regions should really exist around the antidot, although their presence at high magnetic fields is implied by our double-frequency model [3]. Here, we consider two possible cases as depicted in Fig. 1(a) and (b). The first case is with a well-defined compressible region [Fig. 1(a)] and fairly sharp transitions to incompressible regions (over a distance of order the magnetic length). All the compressible states stay within about $k_{\mathrm{B}}T$ of E_{F} [8]. Here, increasing T does not change the number of states involved in tunnelling, unless the increase is enough to involve neighbouring incompressible states. Even so, as there are usually many compressible states, involving a few more states would make little difference, and hence a $1/T$ dependence is expected. The results of Karakurt *et al.* cannot distinguish this potential from a steeply-sloping potential, where the single-particle level spacing is much greater than $k_{\mathrm{B}}T$ [Fig. 1(c)].

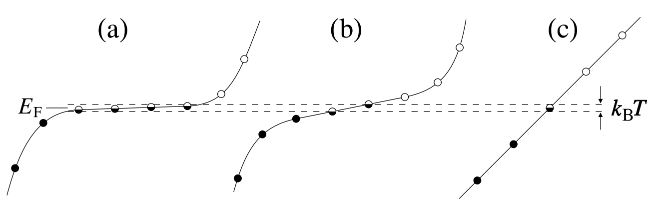

FIG. 1: The Landau level near the Fermi energy around an antidot with (a) a well-defined compressible region around the antidot, where all the compressible states are pinned within $k_{\mathrm{B}}T$; (b) an incomplete compressible region, where its energy width is larger than $k_{\mathrm{B}}T$, but the single-particle level spacing is smaller than or comparable to $k_{\mathrm{B}}T$; (c) a steeply-sloping potential, where a compressible region does not form and the level spacing is much larger than $k_{\mathrm{B}}T$.

The second possibility is that the potential slopes more, since screening is imperfect [Fig. 1(b)]. Here, the single-particle level spacing is smaller than or comparable to $k_{\mathrm{B}}T$, but the energy width of the region of reduced slope exceeds $k_{\mathrm{B}}T$. In this case, the multiple-state theory is valid, and a temperature-independent tunnelling conductance is expected. The results obtained by Karakurt *et al.* only exclude such imperfect compressible regions.

We also wish to point out that we mentioned [3] that our self-consistent model is only expected to work at relatively large magnetic fields (~ 3 T). It is very interesting to ask [9] whether compressible regions should form fully at the small fields (< 1 T) used by Karakurt *et al.*.

In addition, the explanation given by Karakurt *et al.* for double-frequency is pure speculation. They only *assume* that there should be i equally spaced resonances when i Landau levels form antidot states. While this would probably give i resonances per h/e of flux, there is no reason why they should be equally spaced [4, 5]. Also, this would give h/e oscillations when the constrictions were narrowed to filling factor 1, whereas we observe the absence of any oscillations (showing the $\nu = 1$ plateau) until the constrictions are narrowed enough for tunnelling via the lowest spin state (see Fig. 1 in Ref. 3).

M. Kataoka and C. J. B. Ford
Cavendish Laboratory
Madingley Road,
Cambridge CB3 0HE, UK

References

[1] I. Karakurt *et al.*, Phys. Rev. Lett. **87**, 146801 (2001).
[2] D. B. Chklovskii, B. I. Shklovskii, and L. I. Glazman, Phys. Rev. B **46**, 4026 (1992).
[3] M. Kataoka *et al.*, Phys. Rev. B **62**, R4817 (2000).
[4] C. J. B. Ford *et al.*, Phys. Rev. B **49**, 17456 (1994).
[5] A. S. Sachrajda *et al.*, Phys. Rev. B **50**, 10856 (1994).
[6] M. Kataoka *et al.*, Phys. Rev. Lett. **83**, 160 (1999).
[7] C. W. J. Beenakker, Phys. Rev. B **44**, 1646 (1991).
[8] K. Lier and R. R. Gerhardts, Phys. Rev. B **50**, 7757 (1994).
[9] M. Kataoka *et al.*, Phys. Rev. Lett. **89**, 226803 (2002).